

# AN UPPER JURASSIC THEROPOD DINOSAUR FROM THE SECTION 19 MINE, MORRISON FORMATION, GRANTS URANIUM DISTRICT

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**ABSTRACT.**—Known vertebrate fossil occurrences from Jurassic strata in the mines in the Grants uranium district are few. Here, we describe fragmentary teeth, skull, and jaw elements that probably pertain to the theropod dinosaur *Allosaurus*. These fossils were recovered from the Upper Jurassic Salt Wash (=Westwater Canyon) Member of the Morrison Formation in the underground workings of the Section 19 mine near Grants, New Mexico. If properly identified, these fossils are the stratigraphically lowest occurrence (LO) of *Allosaurus* in New Mexico and one of the oldest records of *Allosaurus* in the Morrison Formation.

## INTRODUCTION

Miners in the Grants uranium district doubtless encountered dinosaur bones relatively frequently, but very few of these discoveries were ever documented (Chenoweth, 1953; Smith, 1961) and even fewer were repositied in museums (Hunt and Lucas, 1993; Lucas et al., 1996). In this paper, we document fragmentary tooth-bearing dinosaur bones and associated teeth from the Morrison Formation Section 19 mine and discuss their biostratigraphic significance (Fig. 1). Throughout this paper, NMMNH refers to the New Mexico Museum of Natural History and Science, Albuquerque, and UMNH refers to the Utah Museum of Natural History, Salt Lake City.

## PREVIOUS STUDIES

*Allosaurus* fossils in New Mexico are both rare and fragmentary. The first report of *Allosaurus* remains in New Mexico was from work during the summer of 1953, when W. L. Chenoweth and J. E. Self collected dinosaur remains from the Morrison Formation, near both Acoma and Suwanee Peak (Cibola County), that were later identified by E. H. Colbert to include *Allosaurus* (Smith, 1961). Rigby (1982) reported *Allosaurus* cf. *A. fragilis* teeth, which were found in 1978, from the Morrison Formation near San Ysidro, in Sandoval County and later identified by James Madsen. Isolated teeth and other bones of *Allosaurus* have been reported, but not documented, from Cibola and Quay counties (Lucas et al., 1985; Hunt and Lucas, 1993). Lucas et al. (1996) documented and included photographs of three *Allosaurus* teeth from the San Ysidro dinosaur quarry (NMMNH locality L-3283), also known as the *Camarasaurus* quarry, of Rigby (1982). Foster (2003) recently outlined all vertebrate records in the Morrison Formation of the Rocky Mountain region, including New Mexico, and identified *Allosaurus* remains at the Exeter site in Union County, in addition to the sites in Cibola, Sandoval and Quay Counties mentioned above. The theropod dinosaur from the Peterson quarry (NMMNH locality 3282) near Laguna, New Mexico (Willamson and Chure, 1996; Heckert et al., 2000) is an allosaurid, but is far larger than *Allosaurus* and, thus far, lacks cranial material, so is not comparable to the material we describe here.

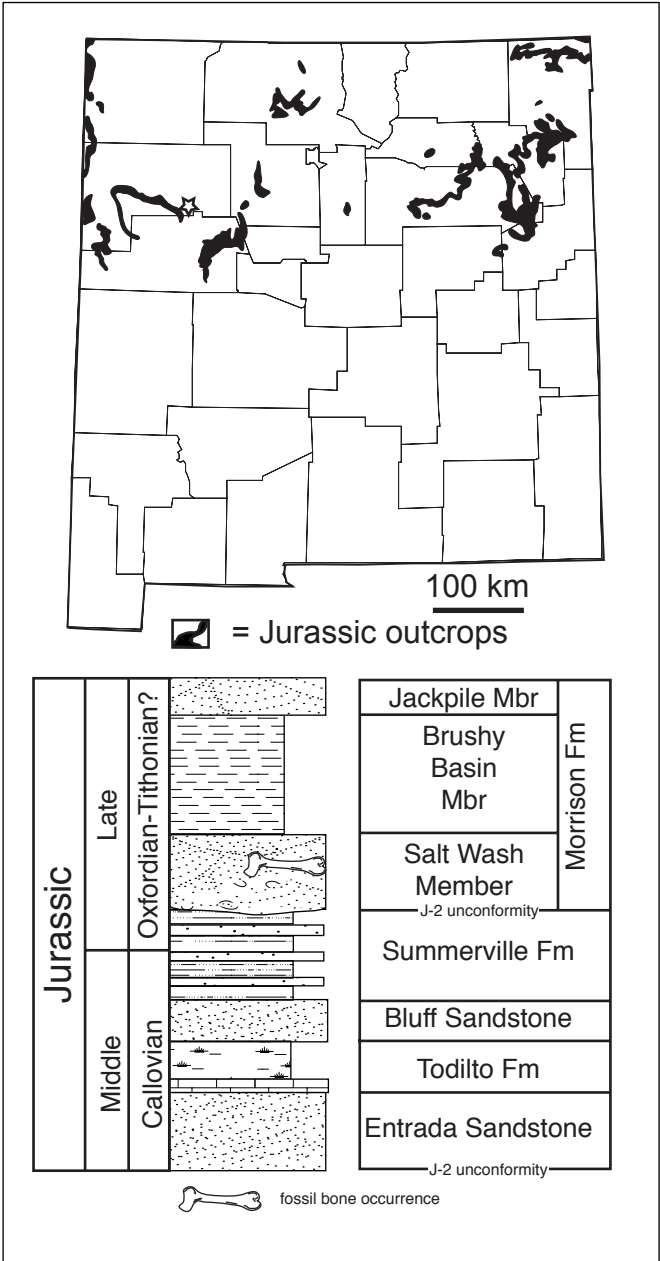


FIGURE 1. Index map and generalized stratigraphic section showing the stratigraphic position of the specimens found here.

## PROVENANCE

The fossils described here were recovered from the underground workings of the Section 19 mine, T14N, R9W, Cibola County, New Mexico, by the junior authors (R. A. and D.M.R.) during mining operations in 1977 (Fig. 1). One of the authors (R.A.) brought some of these fossils to the NMMNH and tracked down his supervisor at the time (D.M.R.), who has loaned the others to the NMMNH for purposes of this study. The fossils were discovered after blasting an access drift in waste rock in stope 4303. At the time, mine operations were in the "Westwater Canyon Member" of the Morrison Formation, and matrix still encrusting some of the fossils is a yellowish gray (5Y7/2 of Goddard et al., 1984), fine-grained, subrounded, moderately poorly sorted sublitharenite.

Following Anderson and Lucas (1995, 1996, 1998), we only recognize three members of the Morrison Formation in the Grants uranium district. These are, in ascending order, the Salt Wash, Brushy Basin, and Jackpile members (Fig. 1). The "Westwater Canyon" Member of economic usage (Gregory, 1938) is clearly synonymous with the Salt Wash Member (Anderson and Lucas, 1996, 1998). Vertebrate fossils from the Morrison Formation occur almost exclusively in the Brushy Basin Member both in New Mexico (Hunt and Lucas, 1993; Lucas et al., 1996; Lucas and Heckert, 2000) and across its outcrop belt in the western U.S. (e.g., Carpenter, 1998; Turner and Peterson, 1999; Foster, 2003). Salt Wash Member dinosaurs are all but unknown in New Mexico (Hunt and Lucas, 1993; Lucas et al., 1996) and limited to just a few generically identifiable records across the Morrison Formation as a whole (e.g., Gillette, 1996; Foster, 2003).

## DESCRIPTION

Due to the unusual circumstances of discovery and collection, the specimen we describe here is somewhat fragmentary (Figs. 2-3). Furthermore, it is apparent that the specimen was disarticulated prior to burial, as the largest block includes a right maxilla and a right dentary, rotated 180 degrees relative to each other (Fig. 2A-D). The specimen (NMMNH P-38975 for fossils in the NMMNH) consists of: a right dentary, with interdental plate, that preserves the first to seventh tooth position and a single tooth in position one (Figs. 2A, D-E, 3); a right dentary fragment with a single tooth and a replacement tooth; a right dentary fragment with a single replacement tooth; another maxillary fragment with two replacement teeth; a third maxillary fragment with a single replacement tooth; three right maxillary teeth (two illustrated in Fig. 2F-G), two left maxillary teeth (Fig. 2F-G); a single right dentary tooth; two left dentary teeth; two right maxillary tooth fragments; three left maxillary tooth fragments; two right dentary tooth fragments; and twelve indeterminate tooth fragments. Oddly, the dentary is conjoined in the same block with a right maxillary fragment that has been rotated 180 degrees from its initial position. This maxillary fragment has five preserved tooth positions, three of which bear fully erupted teeth, and a replacement tooth (Figs. 2B-D, 3B-C). There is no duplication of unique elements, and all of the fossils were found together in a small area

that the uranium miners took to be a single skull. Therefore, even though the bones were obviously somewhat disarticulated, there is no reason to assume that there is more than one individual or taxon preserved as NMMNH P-38975.

The two most diagnostic elements are the maxilla and dentary fragment that are in the same block. As of this writing, this part of the specimen is still in the possession of Russell. As preserved, the large dentary fragment measures 137 mm long, 49 mm high, and 30 mm wide, and the maxilla fragment measures 102 mm long, 60 mm high, and 22 mm wide. The single tooth in the dentary is in the anteriormost (first) position, and is recurved, serrated and lacks longitudinal grooves. The maxilla fragment preserves three consecutive, nearly complete teeth. These teeth are recurved, serrated and laterally compressed. The serrations on these teeth are fine, with a denticle density of 2-3/mm. The lateral (external) surface of the maxilla is heavily ornamented, with both the typical line of nutrient foramina and a more unusual pattern of faintly radial, deeply incised grooves.

The fragmentary nature of these specimens prevents us from assigning them to the typical Morrison Formation taxon *Allosaurus* on a cladistic basis. Numerous phylogenetic analyses have been conducted on theropod dinosaurs (e.g., Holtz, 1994, 2000), but when discussing synapomorphies of the Allosauridae or *Allosaurus* specifically, they refer solely to postcranial material for these taxa. Accordingly, we rely on comparison to *Allosaurus* (Madsen, 1976) and *Ceratosaurus* (Madsen and Welles, 2000), and therefore assign this specimen to the Allosauridae based on features of the conjoined right dentary and right maxilla. The only other reasonably common large theropod present during this time interval is *Ceratosaurus*. This specimen is not *Ceratosaurus* based on two main characters. First, there is no lingual groove on the first tooth of the dentary, a diagnostic feature of *Ceratosaurus* (Madsen and Welles, 2000, fig. 11). Second, the nutrient foramina on the maxilla are present directly above the maxillary teeth (Fig. 2B-C, 3B), as in *Allosaurus* (Madsen, 1976, pl. 1), not slightly above the maxillary teeth and with an associated groove, as in *Ceratosaurus* (Madsen and Welles, 2000, pl. 10). The specimen has several other characteristics that are typical, if not diagnostic, of the Allosauridae. These include a foramen below the Meckelian groove and directly under the fourth tooth position of the dentary (Figs. 2A, 3A) as seen in *Allosaurus* (Madsen, 1976, pl. 9, fig. 10). The dentary's shape is more or less linear (Figs. 2A, 3A). It is not the angled dentary seen in other theropods of the time, although of large Morrison Formation theropods, only *Allosaurus*, *Ceratosaurus*, *Marshosaurus* and *Torvosaurus* are known from cranial material (Molnar, 1990; Molnar et al., 1990; Britt, 1991; Madsen and Welles, 2000). Of these theropods, the preserved material most closely resembles *Allosaurus* and is clearly not *Ceratosaurus*. D. Chure (pers. comm., 2003) also agrees that the Salt Wash fossils we document here are not referable to *Marshosaurus* or *Torvosaurus*. The medial symphysis on the dentary (Fig. 2A, 3A) is angular and similar in appearance to *Allosaurus* (Madsen, 1976, pl. 9, fig. d).

We compiled data (Table 1) on the crown height, fore-aft basal length, and fore and aft denticle density, following Farlow et al. (1991) and Carr and Williamson (2000), for the teeth from the

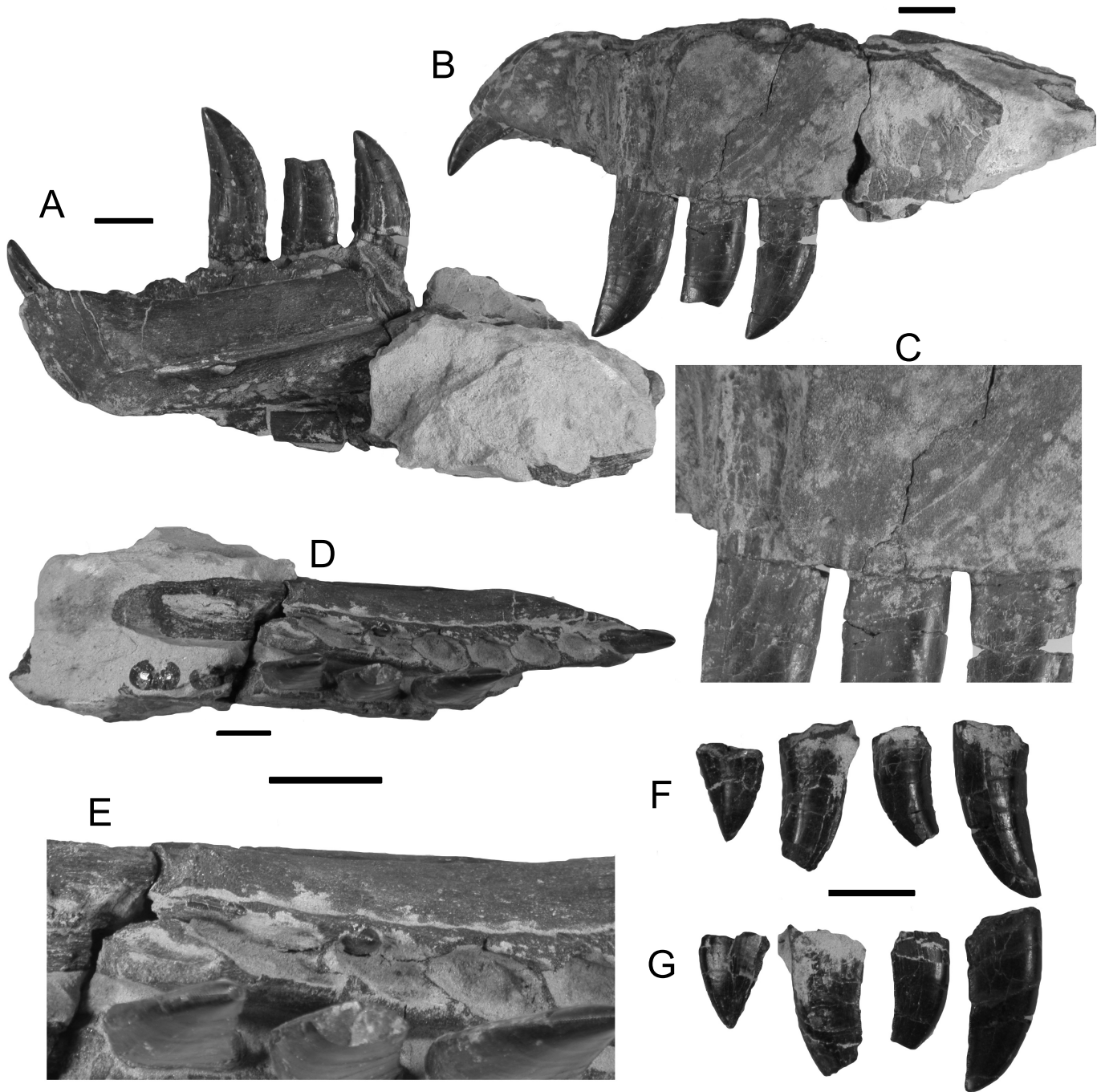


FIGURE 2. Photographs of *Allosaurus* from Section 19 mine. A. right dentary in lingual view with right maxilla in the background. B. right maxilla in lateral view with right dentary in background. C. close-up of right maxilla showing nutrient foramina above maxillary teeth. D. right dentary in dorsal view, right maxilla in ventral view. E. close-up of right dentary showing interdental plates and replacement tooth. F. left maxillary teeth in lingual view (the two teeth on the left) and right maxillary teeth in labial view (the two teeth on the right). G. left maxillary teeth in labial view (the two teeth on the left) and right maxillary teeth in lingual view (the two teeth on the right). All scale bars equal 2cm.

Section 19 mine specimen, known *Allosaurus* teeth specimens on loan from the UMNH, and other *Allosaurus* teeth specimens in the NMMNH. The table shows that the Section 19 mine specimen bears similar denticle density numbers to those of the *Allosaurus* specimens from both UMNH and NMMNH; namely, that their fore and aft denticle densities are equal or nearly equal. This

is obviously an extremely preliminary analysis. Most work on theropod tooth variation has focused on Cretaceous theropods (e.g., Farlow et al., 1991; Carr and Williamson, 2000; Sankey, 2002). However, the densities we document here are slightly finer than the 2/mm we measured for *Ceratopsaurus* from Madsen and Welles (2000, fig. 2).



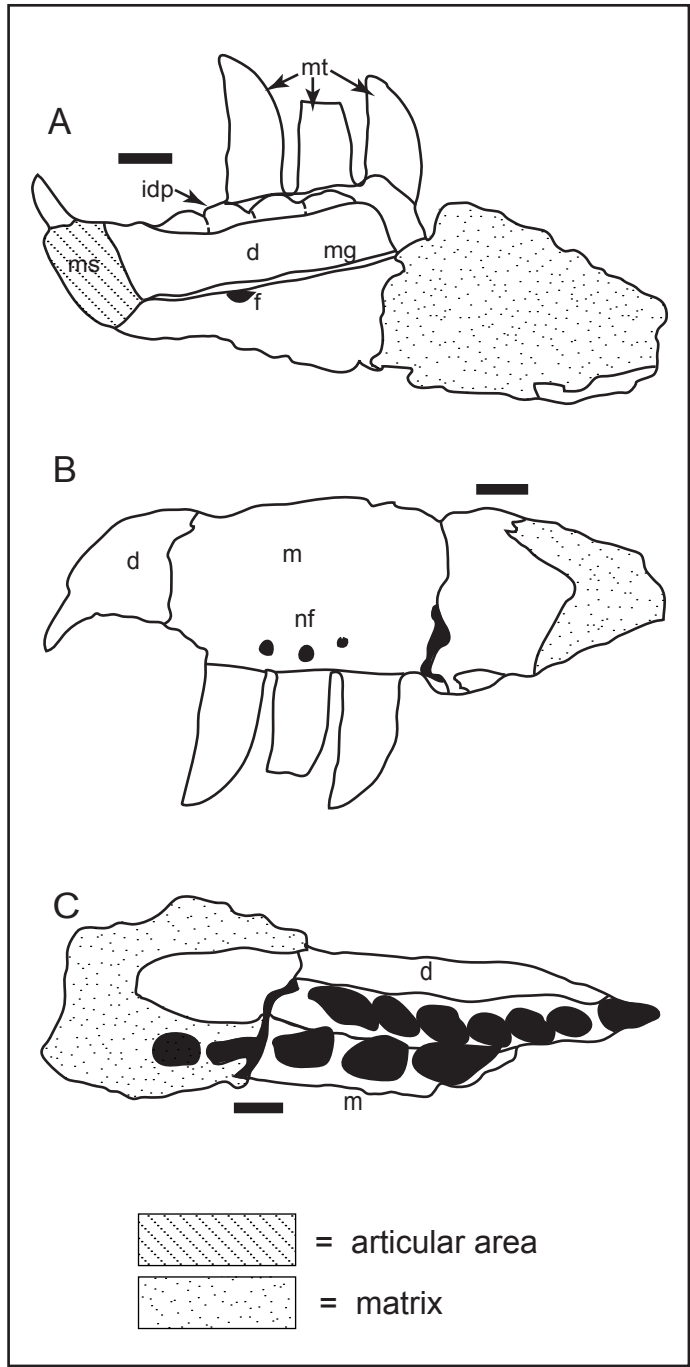


FIGURE 3. Interpretative sketches of *Allosaurus* from Section 19 mine. A. right dentary in lingual view with right maxilla in the background. B. right maxilla in lateral view with right dentary in background. C. right dentary in dorsal view, right maxilla in ventral view. All scale bars equal 2cm. Abbreviations: d = dentary, f = foramen, idp = interdental plates, m = maxilla, mg = Meckelian groove, ms = medial symphysis, mt = maxillary teeth, nf = nutrient foramina.

DISCUSSION

The Section 19 mine theropod fossils, from the Salt Wash Member, are some of the oldest Morrison theropods known. Radioisotopic ages and microfossils from the Tidwell Member of

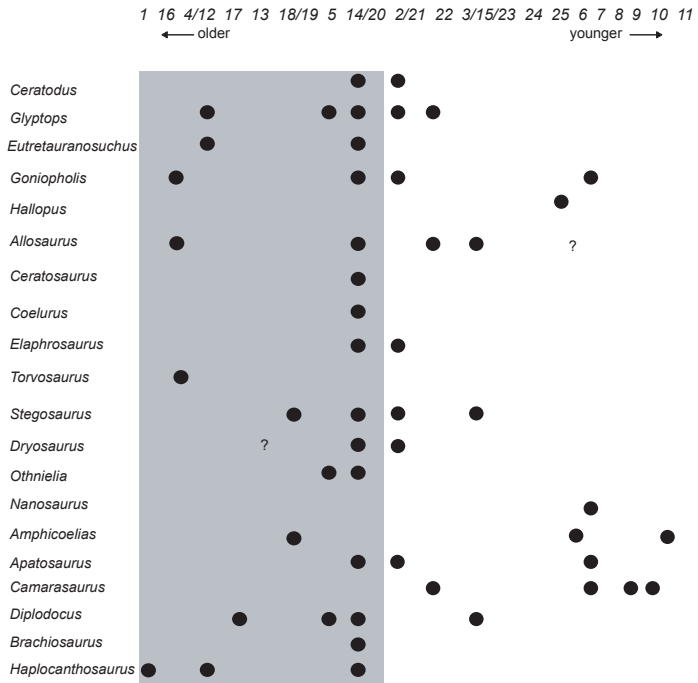


FIGURE 4. Stratigraphic distribution of vertebrate taxa from the Morrison Formation in the Garden Park Paleontological Resource Area in Colorado (based on data in Carpenter, 1998). The gray shaded box indicates the *Haplocanthosaurus* biozone of Carpenter, which is succeeded by his *Camarasaurus* biozone.

the upper Summerville Formation, which underlies the Morrison Formation throughout New Mexico, suggest that it is of Oxfordian age (Peterson et al. 1993; Shudack et al., 1998). Magnetostratigraphy and radioisotopic ages indicate that the upper part of the Morrison Formation may be as young as Tithonian and locally, it may even range into the earliest Cretaceous. The Morrison Formation thus may encompass part of Oxfordian time, and all of Kimmeridgian and Tithonian time (Fig. 1), which is at least 10 million years on any recently published numerical time scale.

Despite its apparent long duration, the Morrison Formation vertebrate fauna appears to be a single chronofauna that changed little during the timespan of Morrison deposition. Recognizing this, Lucas (1993) introduced the term Comobluffian land-vertebrate faunachron to refer to the interval of Late Jurassic time characterized by the Morrison Formation chronofauna. Attempts at biostratigraphic subdivision of the Comobluffian either lack a foundation in lithostratigraphy (e.g., Bakker et al., 1990; Carpenter, 1998) or are based on questionable lithostratigraphic principles (Turner and Peterson, 1999; refuted by Trujillo, 2002).

For example, Carpenter (1998) proposed two Morrison biozones based on the stratigraphic distribution of vertebrates in the Garden Park Paleontological Resource Area of Colorado (Fig. 4). The lower *Haplocanthosaurus* biozone is essentially from the Salt Wash Member, whereas the upper *Camarasaurus* biozone is from the Brushy Basin Member. The lack of general utility of Carpenter's (1998) biozones is demonstrated by the fact that *Camarasaurus* is found in the Tidwell Member of the Summerville Formation (Hunt and Lucas, 1993; Lucas et al., 1996)

TABLE 1. Comparative measurements of *Allosaurus* teeth.

Tooth type	SECTION 19 MINE SPECIMEN			
	Fore-aft basal length (mm)	Crown height (mm)	Denticle density (per 5 mm)	
			Fore	Aft
Right maxillary tooth(Fig. 2F,G on right)	17.3	38.8	13	12
Right dentary tooth (1 <sup>st</sup> position)	11.1	27.8	10	9
Right maxillary tooth (Fig. 2B, left tooth)	23.0	44.0	15	14
Right maxillary tooth (Fig. 2B, middle tooth)	20.9	29.0 AP	17	12
Right maxillary tooth (Fig. 2B, right tooth)	20.8	42.6	12	12

MEASUREMENTS OF OTHER <i>ALLOSAURUS</i> TEETH				
Specimen number	Fore-aft basal length (mm)	Crown height (mm)	Denticle density (per 5 mm)	
			Fore	Aft
UMNH 5754	12.8	24.0 AP	15	14
UMNH 5812	11.5	22.5	13	12
UMNH 5814	13.7	29.2	11	12
UMNH 5837	15.3	32.9	12	11
UMNH 6100	11.9	24.8	12	10
UMNH 6140	15.0	36.0	13	15
UMNH 6142	20.6	42.8	14	11
UMNH 6145	11.1	23.0	10	10
UMNH 6153	18.5	41.5	12	11
UMNH 6233	17.0	38.6	13	12
UMNH 6234	12.3	21.5	13	14
UMNH 6237	17.1	35.3	9	11
UMNH 6242	19.6	41.5	11	11
UMNH 7442	15.7	31.6	10	10
UMNH 7445	18.9	35.1	11	11
NMMNH 26086	21.3	43.0	10	12
NMMNH 26087	18.1	31.8	10	12

AP = as preserved

and in the Salt Wash Member of the Morrison Formation as well (Ikejiri, 2002), so it has a much longer stratigraphic distribution than its limited record at Garden Park.

### CONCLUSIONS

Identifiable dinosaur fossils from the uranium mines in the Morrison Formation are rare, and few, if any, were repositied in museums. The specimen described here, albeit fragmentary, is sufficiently complete to identify as cf. *Allosaurus*. Indeed, this turns out to be one of the oldest records of the genus, as almost all other records of *Allosaurus* are from the overlying Brushy Basin Member of the Morrison Formation (Foster, 2003). We hope that articles such as this spur others with similar fossils in their possession to bring them to our attention. The data from fossils such as these is invaluable, but lost to science as long as these specimens remain hidden in private hands. For example, this specimen is the stratigraphically oldest record from New Mexico, but was unknown to science until a chance encounter between two of the authors brought it to light.

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### REFERENCES

- Anderson, O. J. and Lucas, S. G., 1995, Base of the Morrison Formation, Jurassic, of northwestern New Mexico and adjacent areas: New Mexico Geology, v. 17, p. 44-53.
- Anderson, O. J. and Lucas, S. G., 1996, The base of the Morrison Formation (Upper Jurassic) of northwestern New Mexico and adjacent areas: Museum of Northern Arizona Bulletin 60, p. 443-455.
- Anderson, O. J. and Lucas, S. G., 1998, Redefinition of Morrison Formation (Upper Jurassic) and related San Rafael Group strata southwestern U.S.: Modern Geology, v. 22, p. 39-69.
- Bakker, R.T., Carpenter, K., Galton, P.M., Siegarth, J., and Filla, J., 1990, A new latest Jurassic vertebrate fauna, from the highest levels of the Morrison Formation at Como Bluff, Wyoming: *Hunteria*, v. 2, p. 1-20.
- Britt, B.B., 1991, The theropods of the Dry Mesa Quarry (Morrison Formation), with emphasis on the osteology of *Torvosaurus tanneri*: Brigham Young

- University Geology Studies, v. 27, p. 1-72.
- Carpenter, K., 1998, Vertebrate biostratigraphy of the Morrison Formation near Cañon City, Colorado: *Modern Geology*, v. 23, p. 407-426.
- Carr, T. D. and Williamson, T. E., 2000, A review of Tyrannosauridae (Dinosauria, Coelurosauria) from New Mexico: *New Mexico Museum of Natural History and Science, Bulletin* 17, p. 113-145.
- Chenoweth, W. L., 1953, The variegated member of the Morrison Formation in the southeastern part of the San Juan Basin Valencia County, New Mexico: [M. S. thesis]: Albuquerque, University of New Mexico, 73 p.
- Farlow, J. O., Brinkman, D. L., Abler, W. L., and Currie, P. J., 1991, Size, shape and serration density of theropod dinosaur lateral teeth: *Modern Geology*, v. 16, p. 161-198.
- Foster, J. R., 2003, Paleocological analysis of the vertebrate fauna of the Morrison Formation (Upper Jurassic), Rocky Mountain region, USA: *New Mexico Museum of Natural History and Science, Bulletin* 23, 100 p.
- Gillette, D. D., 1999, Stratigraphic position of the sauropod *Dystrophiaeus viaemalae* Cope 1877 and its evolutionary implications: *Museum of Northern Arizona, Bulletin* 60, p. 59-68.
- Goddard, E.N., Trask, P.D., DeFord, R.K., Rove, O.N., Singewald, G.T.J., and Overbeck, R.M., 1984, Rock color chart: Boulder, Geological Society of America.
- Gregory, H. E., 1938, The San Juan Country: U.S. Geological Survey, Professional Paper 188, 123 p.
- Heckert, A.B., Lucas, S.G., Zeigler, K.E., Peterson, R.E., Peterson, R.E., and D'Andrea, N.V., 2000, Stratigraphy, taphonomy and new discoveries from the Upper Jurassic (Morrison Formation: Brushy Basin Member) Peterson quarry, central New Mexico: *New Mexico Museum of Natural History and Science, Bulletin* 17, p. 51-59.
- Holtz, T. R., Jr. 1994, The phylogenetic position of the Tyrannosauridae: implications for theropod systematics: *Journal of Paleontology*, v. 68, p. 1100-1117.
- Holtz, T. R., Jr. 2000, A new phylogeny of the carnivorous dinosaurs: *Gaia*, v. 15, p. 5-61.
- Hunt, A. P. and Lucas, S. G. 1993, Jurassic vertebrates of New Mexico: *New Mexico Museum of Natural History and Science, Bulletin* 2, p. 71-75.
- Ikejiri, T., 2002, Biostratigraphic and geographic distribution of *Camarasaurus* (Dinosauria, Sauropoda) from the Morrison Formation: *Geological Society of America, Abstracts with Programs*, v. 34, no. 6, p. 425.
- Lucas, S.G., 1993, Vertebrate biochronology of the Jurassic-Cretaceous boundary, North American Western Interior: *Modern Geology*, v. 18, p. 371-390.
- Lucas, S.G., and Heckert, A.B., 2000, Jurassic dinosaurs in New Mexico: *New Mexico Museum of Natural History and Science, Bulletin* 17, p. 43-45.
- Lucas, S. G., Kietzke, K. K., and Hunt, A.P., 1985, The Jurassic System in east-central New Mexico: *New Mexico Geological Society, Guidebook* 36, p. 213-242.
- Lucas, S. G., Williamson, T. E., Estep, J. W., Hunt A. P., and Anderson, O. J. 1996, Jurassic fossil vertebrates from New Mexico: *Museum of Northern Arizona, Bulletin* 60, p. 235-241.
- Madsen, J. H., Jr., 1976, *Allosaurus fragilis*: a revised osteology: *Utah Geological Survey, Bulletin* 109, p. 163 p.
- Madsen, J. H., Jr. and Welles, S. P., 2000, *Ceratosaurus* (Dinosauria, Theropoda) a revised osteology: *Utah Geological Survey, Miscellaneous Publications* 00-2, p. 80 p.
- Molnar, R.E., 1990, Problematic Theropoda: "carnosaurs"; in Weishampel, D. B., Dodson, P., and Osmólká, H., eds., *The Dinosauria*: Berkeley, University of California Press, p. 306-317.
- Molnar, R. E., Kurzanov, S. M., and Dong, Z., 1990, Carnosauria; in Weishampel, D. B., Dodson, P., and Osmólká, H., eds., *The Dinosauria*: Berkeley, University of California Press, p. 169-209.
- Peterson, F., O'Sullivan, R. B., and Condon, S. M., 1993, Correlation controversies-Middle and Upper Jurassic stratigraphy of the Colorado Plateau as related to northwestern New Mexico: *New Mexico Geology*, v. 15, p. 72.
- Rigby, J. K., Jr. 1982, *Camarasaurus* cf. *supremus* from the Morrison Formation near San Ysidro, New Mexico-the San Ysidro dinosaur: *New Mexico Geological Society, Guidebook* 33, p. 271-272.
- Sankey, J. T., 2002, Small theropod and bird teeth from the Late Cretaceous (Late Campanian) Judith River Group, Alberta: *Journal of Paleontology*, v. 76, p. 751-763.
- Schudack, M., Turner, C., and Peterson, F., 1998, Biostratigraphy, paleoecology, and biogeography of charophytes and ostracodes from the Upper Jurassic Morrison Formation, Western Interior, U.S.A.: *Modern Geology*, v. 23, p. 379-414.
- Smith, C. T., 1961, Triassic and Jurassic rocks of the Albuquerque area: *New Mexico Geological Society, Guidebook* 12, p. 121-128.
- Trujillo, K. C., 2002, Misuse of clay mineralogy as a correlation tool in the Morrison Formation (Upper Jurassic) of the Western Interior, U.S.A.: *Journal of Vertebrate Paleontology*, v. 22, supplement to no. 3, p.115A.
- Turner, C.E., and Peterson, F., 1999, Biostratigraphy of dinosaurs in the Upper Jurassic Morrison Formation of the Western Interior, U.S.A.: *Utah Geological Survey Bulletin*, v. 99-1, p. 77-114.
- Williamson, T. E. and Chure, D. J., 1996, A large allosaurid from the Upper Jurassic Morrison Formation (Brushy Basin Member), west-central New Mexico: *Museum of Northern Arizona, Bulletin* 60, p. 73-79.